Superconducting RF Module & Test Facility (SM&TF)

Goal: Develop U.S. Capabilities in high gradient and high Q superconducting accelerating structure in support of the International Linear Collider and other accelerator projects of interest to U.S and the world physics community.

Contacts for SMTF

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SMTF Expression Of Interest

- Expression of Interest for the Superconducting Module & Test Facility (SMTF) has been submitted to Fermilab director 10/29/04

- US Institutions Involved in Discussions
  - Argonne Laboratory (ANL),
  - Brookhaven (BNL),
  - Cornell University,
  - Fermilab,
  - Jefferson Laboratory (JLAB),
  - Lawrence Berkeley National Laboratory (LBNL),
  - Los Alamos National Laboratory (LANL),
  - MIT-Bates Laboratory,
  - National Superconducting Cyclotron Laboratory (MSU-NSCL),
  - Northern Illinois University (NIU),
  - Spallation Neutron Source (SNS) at Oak Ridge,
  - University of Pennsylvania
  - Stanford Linear Accelerator Center (SLAC).

- International: TESLA Collaboration, DESY, INFN, KEK

Superconducting Module & Test Facility

SMTF is envisioned as:

- A multi-laboratory collaboration on SRF development over a broad range of applications. The synergy of expertise will benefit all SCRF areas.

- A facility where different module types and linac systems can be tested (some with beam).

- An organization that will develop inter-laboratory collaboration (including non-US participation) on cold linac technology, including module development and fabrication.

- The area specific to ILC will be carried out under ILC direction.
- Fermilab has proposed to host of SMTF at the Meson East Area.

Fermilab Perspective on SMTF

- Following the ITRP recommendation the first imperative is establishment of US-based capability in the fabrication of high gradient superconducting accelerating structures.
  - Expanding upon existing scrf expertise at: Argonne, Cornell, Fermilab Jefferson Lab, MSU
  - Provisional goal is to have three U.S. and one European 1.3 GHz ILC cryomodules under test, with beam, by the end of 2008.

⇒ **Fermilab is committed to providing the US leadership with close coordination with the ILC-Americas collaboration.**

- From Fermilab point of view SMTF is the primary mechanism for providing this leadership while allowing us to simultaneously integrate our ILC and PD R&D activities.
- Infrastructure created for this purpose will be of more general utility to a variety of scrf-based U.S. projects (RIA, 4th generation light sources, ERL's, etc)

Motivations for SM&TF

- Several ambitious SCRF accelerator projects being planned in US
  Examples: International Linear Collider & FELs, Light sources, RIA, PD

- US needs and the SM&TF will provide:
  - a facility where different module types & linac systems can be tested (beam)
  - a collaboration on cold linac technology, module development & fabrication

- SM&TF will allow US to:
  - Take advantage of advances in technology to extend science goals
  - Pursue potential of SCRF
  - Minimize cost of new projects by using most advanced SCRF methods
  - Build cooperation with industry
  - Collaborate & compete effectively with Europe and Asia

- Overlap of national experts at one facility allows exchange of ideas and thus unifies US approach to SCRF-compete better and more effective use of resources

- Build collaboration to prepare/plan to host ILC & build ~1/3 of main linac in US (under direction of ILC-Americas Organization)

Four Main Areas of Program

- ILC
  - Fabricate in US 1.3 GHz cryomodules under ILC Americas leadership
  - Initially two modules are planned
  - Establish high gradient test area
- CW
  - Fabricate high-Q value cryomodules
  - Establish a test area that extends US reach
- Proton Driver
  - Fabricate structures and cryomodules
  - Establish a $\beta<1$ test area
- RIA
  - Fabricate structures and cryomodules
  - Establish a $\beta<1$ test area

SMTF Program Goals

- Demonstrate for ILC 1.3 GHz cavity operation at 35 MV/m with beam currents up to 15 mA at a 1% duty factor in two cryomodules with 8 cavities each.
- Demonstrate for CW applications 20 MV/m cavity operation at Q values > 3E10.
- Demonstrate for the Proton Driver 1.3 GHz, $\beta \sim 0.5$-0.8, elliptical cavity operation at > 15 MV/m at Q > 5E9 and a 1% duty factor with multiple cavities being driven by one klystron.
- Demonstrate for the Proton Driver and related applications high gradient operation in pulsed mode of 1.3 GHz and 325 MHz, $\beta < 1$ cavities and cryomodules.
- Demonstrate individual cavity resonance control with multiple cavities driven from one klystron, using fast ferrite phase shifters, at both 1.3 GHz and 325 MHz
- Demonstration of RIA cavities and cryomodules.

US Laboratories Collaboration: A Model

Cavity Fabrication & Testing

↓

Cryomodule Assembly

↓

Testing at SMTF

- The cryogenic elements of the Linac are developed under Fermilab leadership in collaboration with US and International laboratories and tested at SMTF.
- We expect that in US the 1.3 GHz cryomodules will be developed in collaboration with Jlab, Cornell, ANL, LANL, Fermilab, SLAC and Industry.
- Expanding present industrial, laboratory, and university capabilities to contribute significantly is essential for the success of the ILC.
- Our goal will be to work with and integrate industrial capabilities.

Specific Goals for ILC: SMTF

- Establish a high gradient, 1.3 GHz cryomodule test area at Fermilab with a high quality pulsed electron beam using an upgraded A0 injector.

- Fabricate four 1.3 GHz high gradient cryomodules (eight cavities each) using industrial and laboratory partners in the US.

- The fabrication R&D will be carried out as a collaborative effort under the leadership of Fermilab for the ILC-Americas organization.

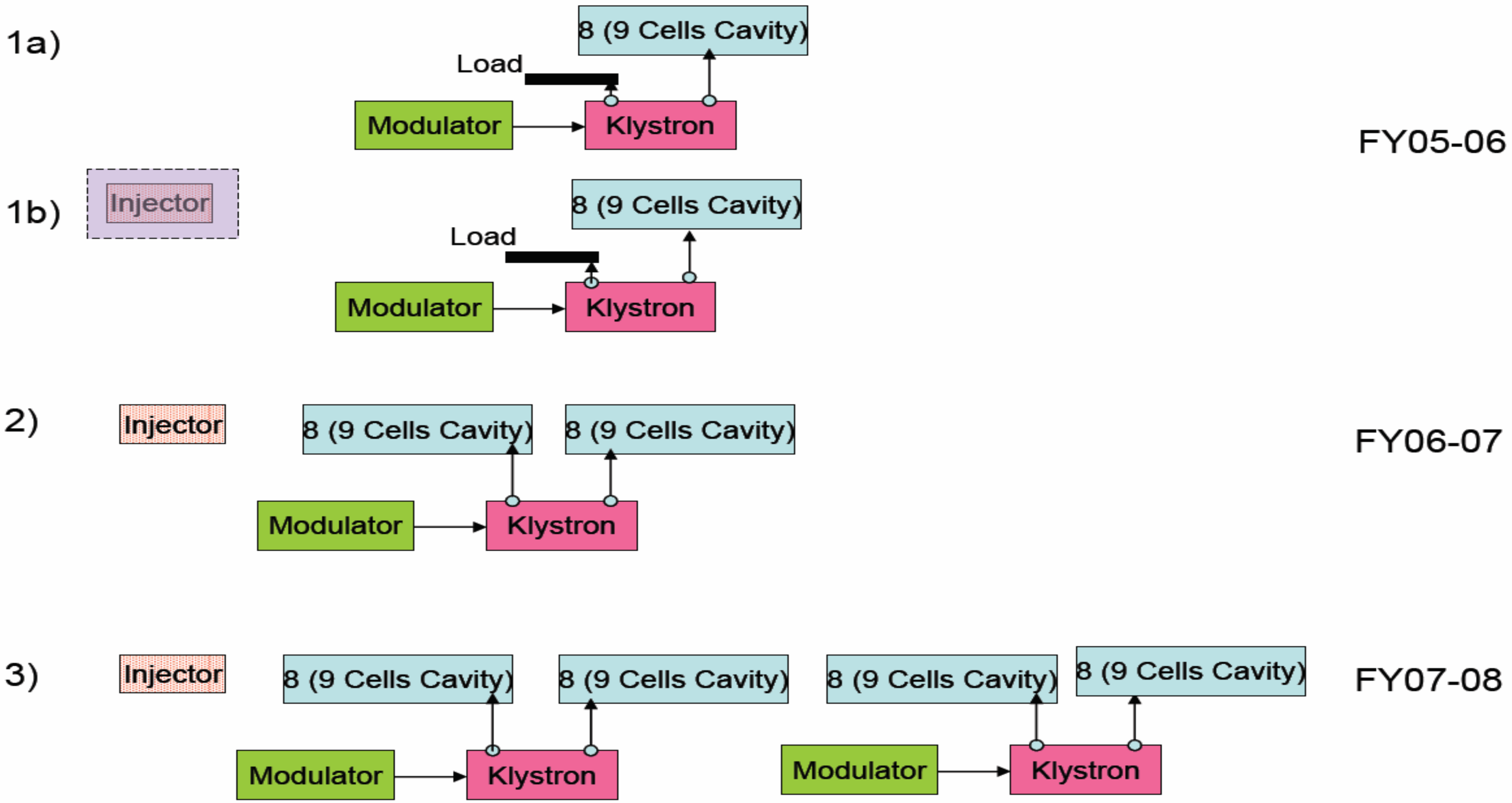
- Test cryomodules and other rf components as fabrication and operation experience is acquired and designs are optimized.

Phases of ILC: SMTF

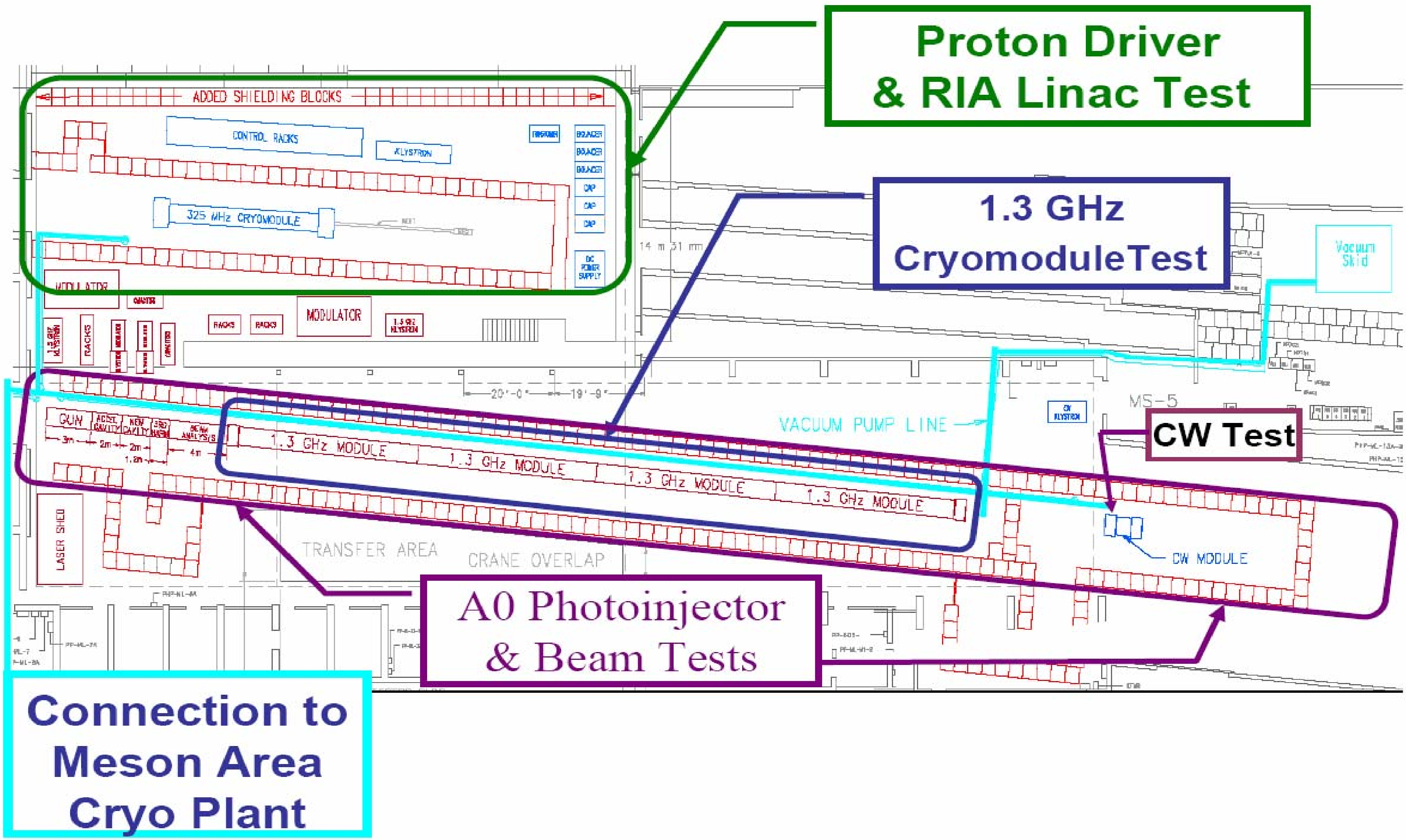
- We propose to bring into operation one cryomodule with the goal of demonstrating 35 MV/m cavity operation. It is expected that it may take more than one module iteration to achieve this gradient.
  - The A0 photo injector will be moved, installed and re-commissioned with the cryomodule (step 1) in order to perform beam measurements, which are discussed below.
  - We will initiate beam tests of a single ILC cryomodule utilizing the photo injector.
- We propose to bring into operation one SMTF-ILC rf unit, defined as two cryomodules each containing eight 9-cell cavities, one high power modulator, one 10 MW multi-beam klystron and perform beam measurements.
  - The injector will be upgraded to include the Fermilab built 3.9 GHz accelerating and deflecting cavities.
- We propose to bring into operation two SMTF-ILC rf units and associated rf power, instrumentation and controls.

SMTF: Three Phase Approach

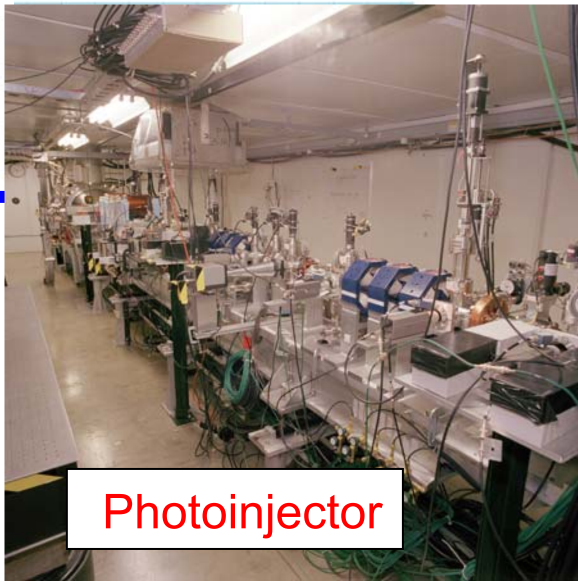
1.3 GHz Cryomodule Test Facility



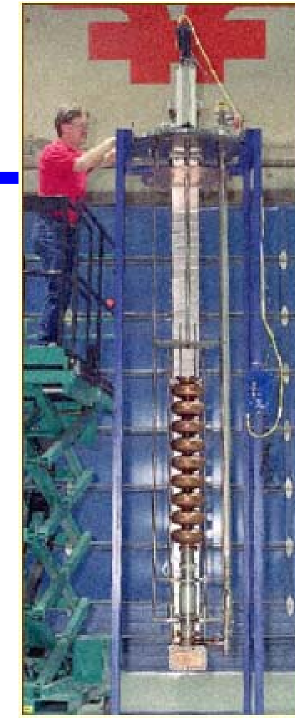
FNAL Meson Area SM&TF Layout Concept



Meson Area Fermilab


Photoinjector


Industrial assembly


Test fixture ("insert")

Fermilab

3.9GHz SRF cavity development
& HOM measurements


Meson Lab

Technology Studies

- Determine the maximum operating gradient of each cavity & its limitations.
- Evaluate gradient spread and its operational implications.
- Measure dark currents, cryogenic load, dark current propagation, and radiation levels.
- Measure alignment of the quadrupole, cavities and BPM in-situ using conventional techniques (e.g. wire or optical).
- Measure vibration spectra of the cryomodule components, especially the quadrupole magnet.
- Measure system trip rates and recovery times to assess availability.
- Develop LLRF exception handling software to automate system and reduce downtime.
- Evaluate failures with long recovery times: vacuum, tuners, piezo controllers, and couplers.

Physics Measurements

- Beam energy: a spectrometer would provide an independent and accurate measurement of the accelerating gradient (rf based techniques are not as accurate).
- Long-range wake-field characterization: Measure frequency spectra of bunch positions downstream of cryomodule to search for high Q cavity dipole modes that could cause beam break-up in the ILC. Correlate these data with HOM power measurements.
- Tests of low-level rf system: demonstrate that a < 0.1% bunch-to-bunch energy spread can be achieved in a 1 msec bunch train.
- Impact of the SCRF cavity on transverse beam dynamics: measure the beam kicks caused by the fundamental mode fields.
- Study beam centering based on HOM dipole signals.

RIA

- The U.S. Rare Isotope Accelerator Project (RIA) will include the construction of nearly 500 superconducting cavities of as many as 10 different types to accelerate ions over a velocity range $0.02 < \beta < 0.85$.

- Cavity types, cryomodules, couplers, and tuners are similar in design to PD

- Rare Isotope Accelerator (RIA) Projects:
  - Cleaning and cold-testing of individual cavities, after chemical processing
  - Clean assembly of cavities into cavity strings, forming a sealed assembly including RF couplers, beam line valves, and vacuum manifold and valves.
  - Assembly of cryomodules incorporating the cavity strings.
  - Cold test of assembled cryomodules.

CW, b=1 Test Facility and Program for Next-Generation Light Sources

- Multi-cell cavity for the ILC, at 1.3 GHz, offers an existing design suitable to application in CW mode to meet the needs of future facilities with modest beam loading (~ 10 μA).
- SMTF would provide a location and infrastructure for development of CW SCRF systems specific to these needs, and complementary to the existing facilities and R&D programs.
- Superconducting RF structures operated in CW mode have advantages in providing high accelerating gradients, extremely stable RF fields, inherently small perturbative effects on the beam, and with lower RF power requirements than normal conducting structures.

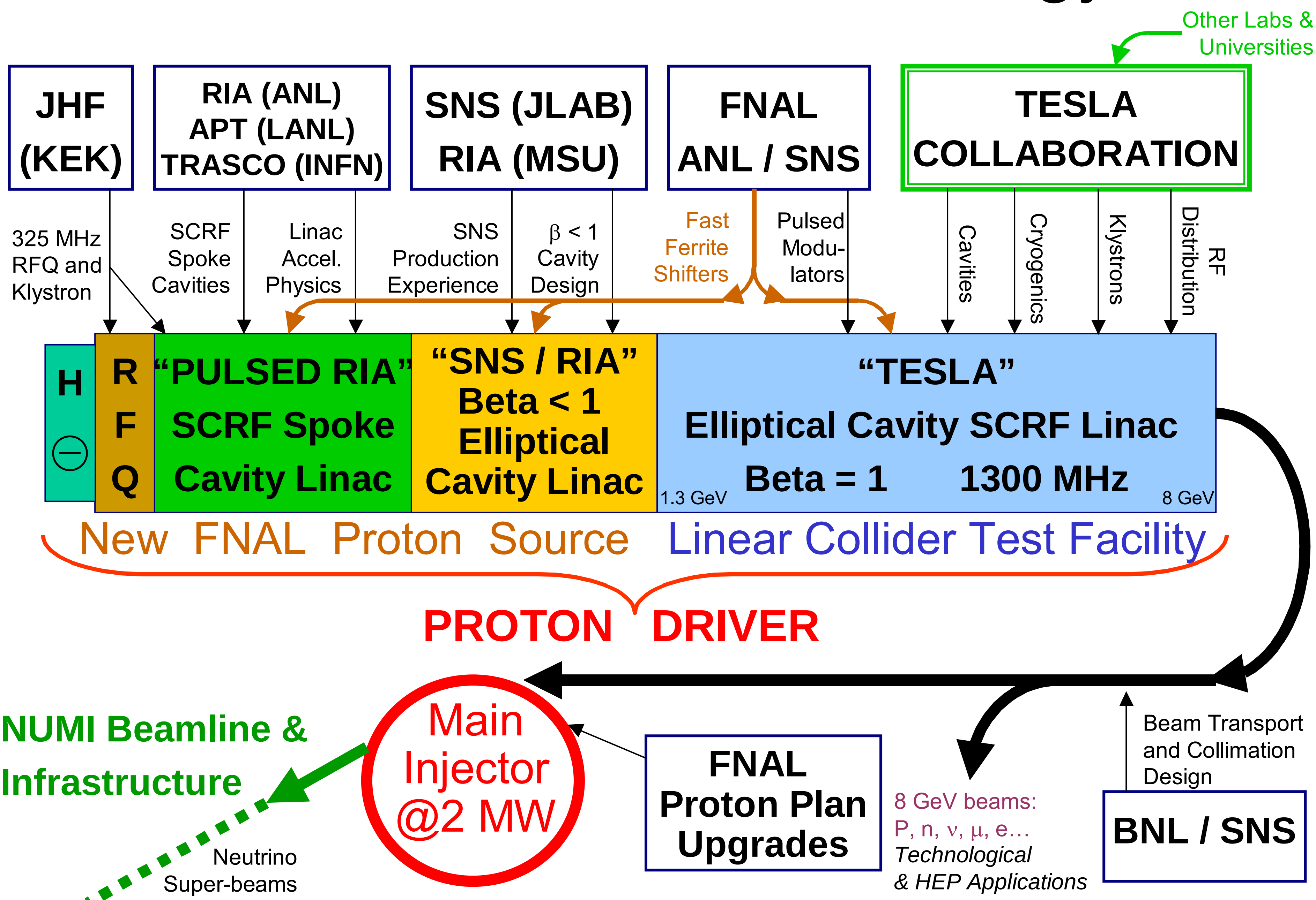
Goals:

- High Q values in CW operations at 20 MV/m, goal of Qo > 3x10E10
- High stability and control of accelerating fields, goals of phase error < 0.01° and amplitude error <1E-4
- The above performance in the presence of electron beam of 1 nC charge, repetition rate ~ 10 kHz

Proton Driver

- The Proton Driver is an 8 GeV SCRF proton linac
  - For Neutrino Super-Beams & other new capabilities at FNAL
- The last 85% of the PD linac (1 GeV to 8 GeV) is *identical to the ILC.*
- Thus, R&D program for the *back end* of the Proton Driver is identical to the ILC ➔ SMTF synergy.
- The Proton Driver represents a 1.5% system test of ILC
  - Useful if funding for ILC construction start is delayed
  - Maintains healthy physics program at FNAL in interim
- R&D for the *front end* of the PD extends technology of SNS, RIA, JPARC, TESLA, and other projects.

Proton Driver Linac - Technology Flow



Summary

- SMTF is the essential first step in realizing ILC with US in a leadership role
- Broad and talented team assembled & good agreement on how to proceed with a US facility for SCRF (EOI submitted)
- International view of SMTF very positive
- Allows a fast start for ILC in US
- SMTF will be important for CW and $\beta<1$ project advancement
- We are starting to work on a formal proposal.